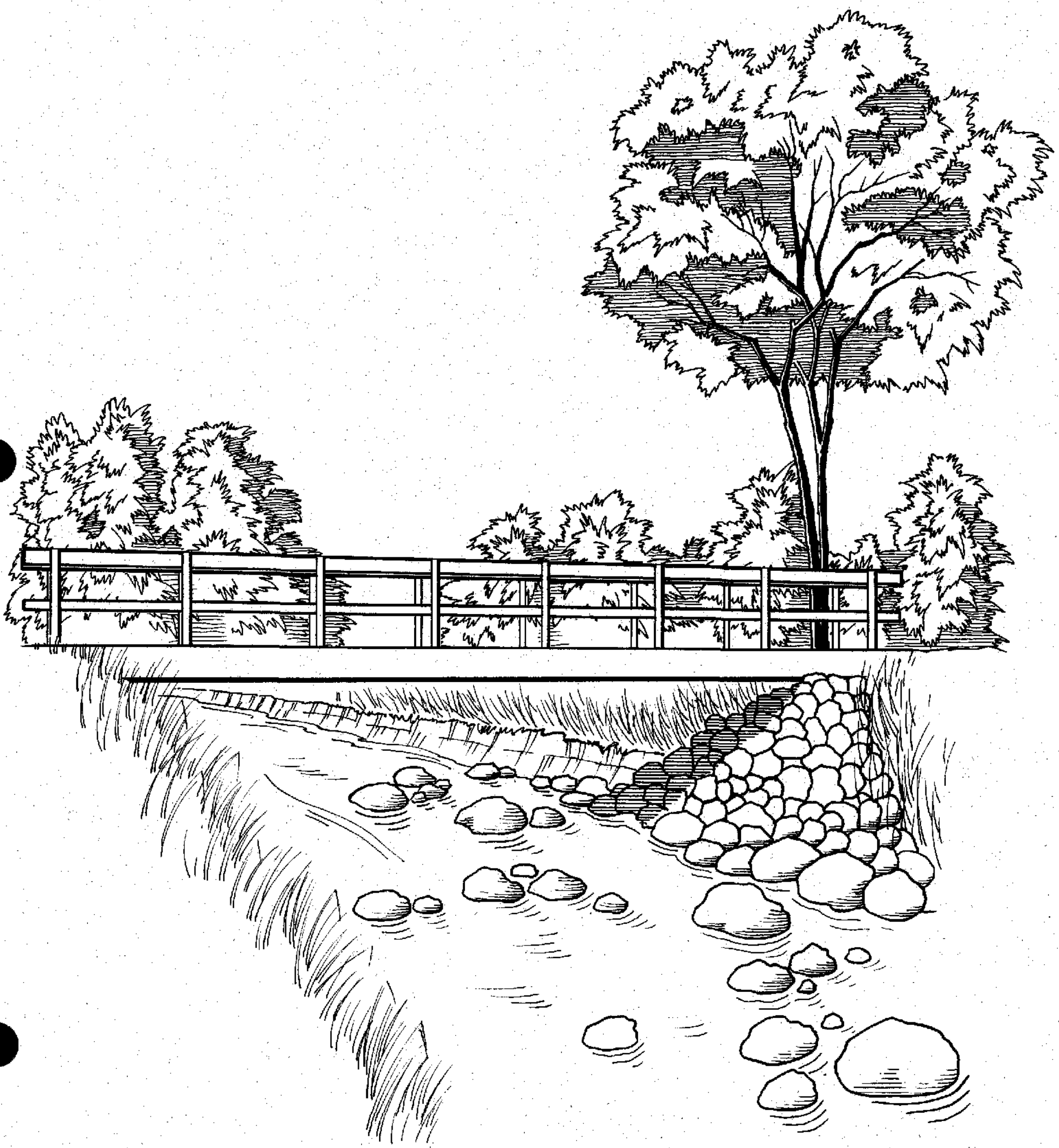
# CHAPTER 5

# TRAIL STRUCTURES



Trail structures discussed in this chapter are those that are necessary for safe passage over wet areas, or topographical or human barriers. Temporary structures and those to avoid are also described. Standards are summarized in Figure 2 (page 5-13).

Trail structures are necessary to meet the demands of various situations. The decision to build a trail structure should be in response to user safety and environmental protection issues—not user convenience issues. Structures require a major commitment of both initial and subsequent costs, time, and maintenance. In addition, construction over designated wetlands or navigable streams can be difficult and require permits. Therefore, whenever possible, the trail should be located to avoid areas with seasonal or year-long water problems. Where wet areas are unavoidable and rerouting is not possible, structural improvements should be used to protect those areas and provide a dry, stable treadway for the Ice Age NST, except during inclement weather or heavy dew. Hikers should not have to wade through streams or saturated wetland areas; this is not only unpleasant and dangerous, but potentially damaging to the environment.

Trail structures should be built of quality, long-lasting material and designed to harmonize with the surrounding environment. Minor structures such as puncheon, turnpike, retaining walls, culverts, and small bridges can be built of suitable native material, if it is available. Rock, as used by the CCC, makes a longer lasting retaining wall, bridge sill, or water bar than wood. Certain species of wood are more durable than others and should be used. If native materials are used, the source site should be left in as natural condition as possible.

## WATER CROSSING STRUCTURES

The State of Wisconsin and Federal governments have rules regarding water crossing structures and placement. Chapter 30, Wisconsin Statutes, requires permits for any work on beds or banks of navigable streams and Section 401 of the Clean Water Act gives the WDNR jurisdiction over wetlands. The Clean Water Act, Section 404 also gives the U.S. Army Corps of Engineers jurisdiction over wetlands and waters of the United States. It is necessary to work closely with the Wisconsin Department of Natural Resources and U.S. Army Corps of Engineers to ensure that all specifications are met and all required permits obtained. It is also recommended that applicants contact local zoning agencies to insure compliance with county, town, city and/or village ordinances. Plenty of lead time is critical as this can be a lengthy process, depending on the stream being crossed and the complexity of the structure. Once the decision has been made to build, you will need to consider the following:

- Any water feature that shows up on a USGS map, intermittent or not, is considered navigable and would require a Wisconsin Statute, Section 30.123 permit, if crossed by a bridge or culvert.
- Bridges spanning 35 feet or more require public notice before building.
- Boardwalks and puncheons, if in a riparian setting, and if below the ordinary high water mark (OHWM) on a navigable water feature, would require a Wisconsin Statute, Section 30.12 permit. These structures should be constructed using high quality materials and building techniques so as to encourage circulation of air and water.

- In wetlands, the use of fill requires a Section 404 permit from the Corps of Engineers. However, the use of fill is discouraged in favor of the structures mentioned above.

To initiate obtaining the necessary permits, or if there is any question on whether a permit is needed, you will need to speak to a WDNR Water Management Specialist. To determine who is the Water Management Specialist for your area, check listings at the following website: www.dnr.state.wi.us/org/water/fhp/people/wms.htm or contact the WDNR office within the region where the site is located. To find which WDNR Region, see Appendix 5 for a Regional Map.

The WDNR Regional office phone numbers are as follows:

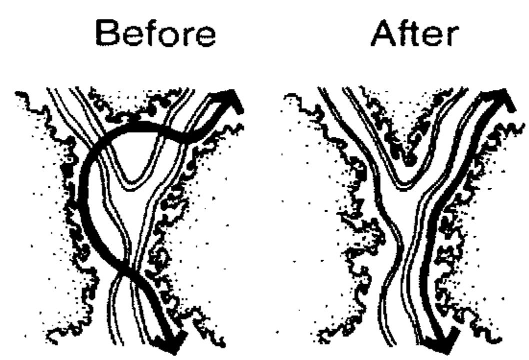
- Northeast Region: Green Bay (920) 492-5800
- Northern Region: Rhinelander (715) 365-8900, Spooner (715) 635-2101
- South Central Region (608) 275-3266
- Southeast Region: Milwaukee (262) 263-8500
- West Central Region: Eau Claire (715) 839-3700

The WDNR Water Management Specialist can tell you whom to call at the Corps of Engineers to obtain federal permits.

Bridges, boardwalks, culverts, and puncheon are four of the most environmentally sound and commonly used structures to cross water. Their descriptions are as follows.

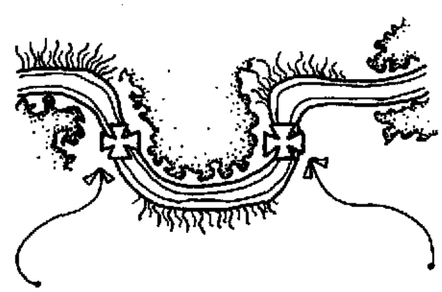
## Bridges

Bridges are structures for crossing permanent and seasonal streams, dry ravines or gorges, and other obstacles in a safe, environmentally sensitive manner. They are also expensive to build, require regular inspections, and need frequent maintenance. All stream crossings and other potential locations for bridges should be reviewed by qualified personnel or engineers to determine whether they are really necessary or if other alternatives, such as rerouting the trail or using a culvert, are better solutions.




The difference between a bridge and other water crossing structures is that it spans a definable stream, ravine, or other obstacle, rather than resting on a long series of sills (puncheon) or posts (boardwalk). However, like a boardwalk, a bridge can have one or more piers. To cross a wetland or general surface water typically requires a boardwalk or puncheon. Situations requiring hybrid solutions may occur where a wetland with a stream flowing through it will have a bridge placed over the stream and a boardwalk constructed over the wetland attached to it.

Safety is a primary reason for constructing any bridge and a consideration in the bridge design. For these reasons, a bridge

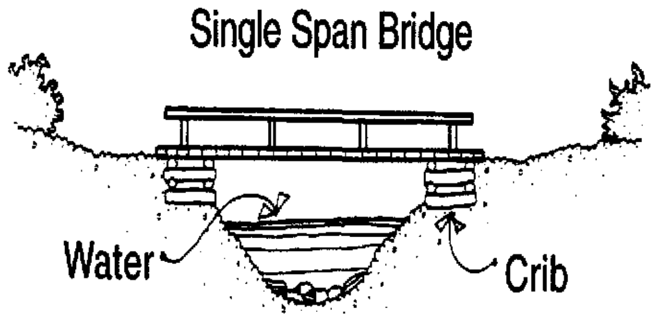


*Best bridge sites are midway between turns.*

is often appropriate when crossing even small streams or dry ravines. One of the best locations for a bridge is where the stream or ravine has a narrow crossing and high banks on both sides to anchor the ends of the bridge. Whenever possible, the entire wet area should be spanned, or ramps built as an approach to an elevated bridge. This eliminates the need for steps, which are an accessibility barrier.

Design of the bridge must provide for clearance of high water, ice, debris and navigation under the bridge during normal flow conditions or at the very minimum a portage around the bridge. Bridges built with an adequate opening to accommodate floodwaters have a better chance of survival. Before initiating any construction drawings, contact the local WDNR Water Management Specialist to obtain this information. When designing a bridge, assistance should be sought from agency partners, private engineering consultants, or other qualified personnel (see Bridge Engineering).

**Bridge Design** - There are many potential bridge designs that ensure adequate public safety. Creativity is encouraged. The look and design of the bridge should emphasize the ROS setting and harmonize with the surrounding landscape. In urban and suburban settings, the bridge may have a polished look; in a semi-primitive setting, it may look more rustic. Whenever you design a bridge, please refer to standards shown in Figure 2, page 5-12.




A ravine or gorge over 10 feet wide can often be crossed with a single-span bridge. Single-span bridges normally require fill or rip rap on each bank, two to three solid timber or laminated support beams, a board deck, railings, etc. In areas where the span becomes too long for a single-span bridge, a suspension bridge may be necessary.

**Bridge width** - Bridges should generally be designed to accommodate the kind of use and the numbers of users expected. They should also be designed to provide for passage of wheelchairs. Bridges allow users to traverse a trail barrier and because they are long-term investments, requiring a substantial commitment of funds, they should not become a barrier in and of themselves. Therefore, the minimum width should be as shown in Figure 2, page 5-12. These widths provide accessibility, even on trail segments that are not specifically designed to be barrier-free or fully accessible.

Consideration should also be given to providing for mowing-equipment crossings, if needed for maintenance beyond the bridge, and in some cases larger maintenance and emergency vehicles. A wider bridge should also be considered in urban locations, areas of high use, or where other user groups, such as bicyclists or horseback riders, may share the trail.

**Bridge railings** - Railings are necessary for safety and to increase visitors' level of comfort. Bridge railings will generally be a minimum of 42″ in height, but may be higher when crossing highways.

**Bridge engineering design** -All trail bridges must be designed to bear loads that meet or exceed current management standards for architectural design and engineering of pedestrian structures, as well as provide for visitor safety, accommodation of flood waters, etc. To achieve this objective, a licensed engineer should either design or review the construction drawings and their elements (stringer size, strength, snowload, peak flows, etc.) prior to construction.

If a bridge is being funded through the National Park Service's Challenge Cost Share Program, the project sponsor should provide information regarding the need for the bridge, a map of its location, copies of permits, and construction drawings that show the bridge's span, height, materials used, and other details. All construction drawings must have the stamp of a licensed engineer.

**Bridge inspection and maintenance** - Bridges require periodic maintenance to insure their stability and safety. Debris should be removed, bolts checked and tightened, sills inspected for rot, etc. All major bridges (>25 feet long or > 5 feet high) should be inspected by qualified personnel at least once every three years. This inspection should be documented. In addition, trail club members should vigilantly watch for hazardous conditions between inspections, and should also routinely inspect smaller bridges.

## Boardwalks

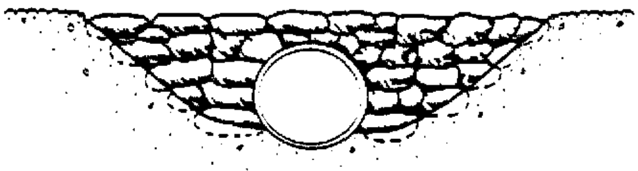
Typical locations where boardwalks can be utilized are cattail and deep marshes, or other water bodies that have little fluctuation in water level and flow. Boardwalks commonly cross areas that have deeper water than can be crossed by puncheon.

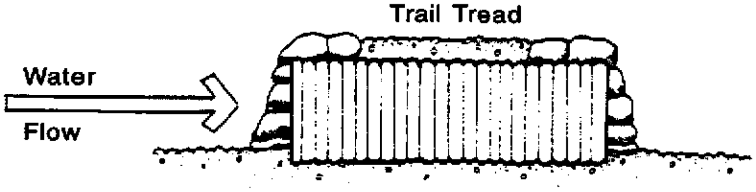
Puncheon is normally less than a foot above the surrounding wetland, while a boardwalk can be 2 to 3 feet above the water, like an elongated dock. Also, the decking on a boardwalk is laid perpendicular to the direction of traffic flow, and the entire structure is supported by posts driven or anchored into the bottom of the wetland, similar to a dock. Boardwalks do not rest on sill logs. Hybrids between boardwalks and puncheon are common. Wetland crossing permits are typically required.

Since boardwalks are a major, long-term investment, and they often cross moderately deep water, the standards specified in Figure 2 should be used to provide a safe crossing and wheelchair passage. Boardwalks are normally made of treated material. If they cross areas of fluctuating water levels, the support posts need to be driven deep into the substrate or anchored in concrete to prevent the boardwalk from lifting or warping. A kickplate should be added to the structure to reduce the chance of falling into the water when the boardwalk is slippery due to rain, frost, or ice. The kickplate also makes the boardwalk safer for wheelchairs. Minimum width of a boardwalk should be 28 inches between the kickplates. Depending on the situation and the desires of the local manager, handrails are optional.

## Culverts

Culverts are cylinder-shaped passages generally made of non-rusting metal or plastic and come in various lengths and diameters. They are used to pass water under the trail, and are an excellent alternative to bridges. Culverts are generally more cost effective than bridges, are easier to install because they come in one piece, and are very unobtrusive. Once a culvert is installed, maintenance is limited to insuring that the interior is kept free of debris and that the soil or riprap around the inlet and outlet is not eroding.



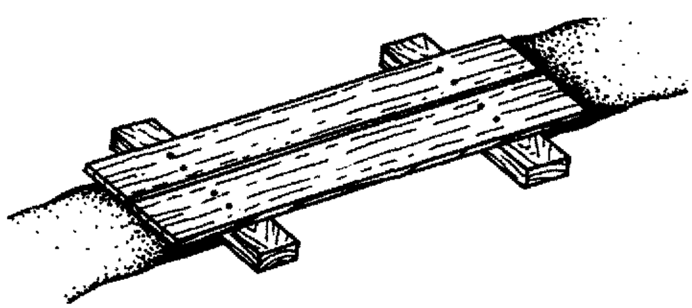

Culverts are most effective for small creeks or intermittent streams with limited peak flows, and in natural drainage-ways, where minimum excavation is required. They also can be used in flat areas to provide equalizing cross-drainage under causeway or turnpike sections, and to reduce the damming effect. They are not appropriate in locations where it is difficult to haul a large and heavy object into the site. Also, at locations where the intent is to draw attention to a stream by providing an aesthetic crossing, or if the experience of the sound of boots on wood decking is important, then a bridge should be built.

As with bridges, professional engineering advice should be sought to insure that the culvert is sufficiently sized to accommodate peak flows. Pipe diameters less than 12 inches may present frequent cleaning problems. If the stream is a navigable waterway, permits will be required. Your local Water Management Specialist can make this determination for you.

Some basic principles should be followed when installing culverts. Culverts should be placed with a gentle down-stream gradient of around 2% and should be properly bedded to ensure continued performance. If metal or plastic pipes are used, a minimum of 6 inches of soil (free of sharp rocks) is recommended for pipe cover, which also provides tread for hikers. Railings protecting the trail user may be attached if the width of the pipe is narrow or long in length.

## Puncheon

A puncheon is an effective way to cross some types of bogs, shallow marshes, and wooded wetlands. A puncheon provides a hardened surface on muddy or wet areas that are not feasible to drain and where environmental damage is a concern. Most puncheons are constructed of wood— often sawed, treated lumber or native logs that elevate the trail's tread above the problematic surface. The boards or logs are laid parallel to the direction of the trail, and the support structures (sills) rest directly on the ground.



Puncheons can be constructed using either native or milled materials and often is a combination of the two. Most typically, the sill logs are made of long-lasting native material (such as cedar, tamarack, locust, etc.) and the walking surface is made of heavy, treated planks. The type of material depends on a number of factors — the distance from an access point, the ability to haul materials to the site, the availability of native materials, the skills available for the difficult job of hewing native puncheon, the desired length of time between replacement, and the ROS setting.

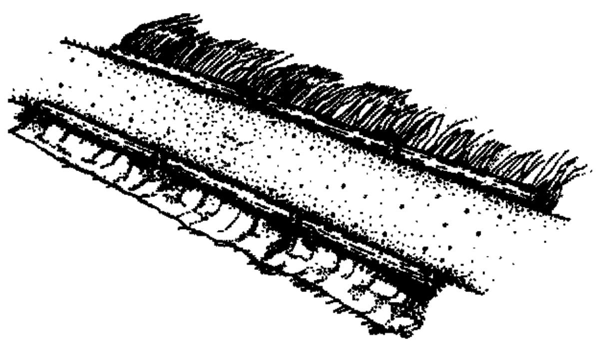
Once the route through a wetland is chosen and the trail is cleared, the first step is to obtain and place the sill logs. These rest directly on the wet soil and vary in length from about 3 feet to 5 or 6 feet, depending on the amount of support provided by the wetland. The stringers (walking surface) are then placed on top of the sill logs and secured in place with large spikes. If native logs are used as stringers, some notching and fitting has to be done so they do not rock on the sills. Puncheons are normally built in 8- to 10-foot sections with no more than 6 inches from the end of one section to the beginning of the next. When treated planks are used, the ends typically rest directly on the sill logs, without gaps between the sections. In this situation, one sill is located directly at the junction between two sets of planks. However, because planks have more flex, a center sill may be needed. In order to achieve the puncheon width specified in Figure 2, two *2" x 8"* or *2" x 10"* planks should be used.

The trail tread at both ends of the puncheon must be solid and dry; otherwise, the stepping-off point may become soft and muddy, eventually requiring the construction of an extra section of puncheon. Adding gravel or rock fill at the ends of the puncheon will help the soil withstand the impact of hikers.

In areas subject to flooding, such as along streams or near beaver activity, a puncheon is not a good choice because it can float out of position or even completely away. In these areas, relocating the trail or using boardwalk should be considered (provided it is protected from spring floods along streams).

## OTHER TRAIL STRUCTURES

### Causeway or Turnpike



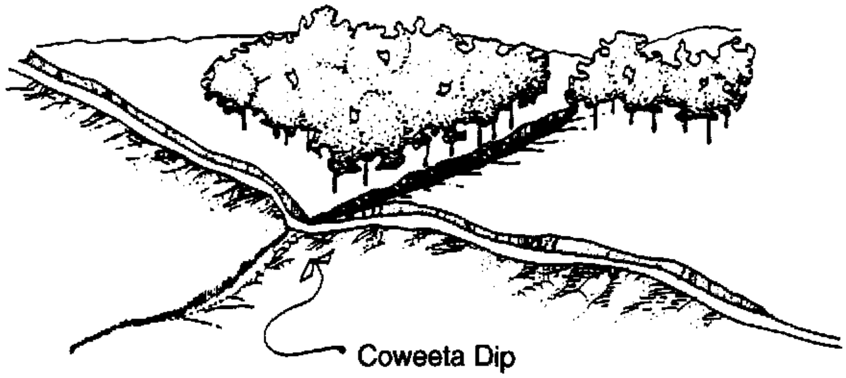
The trail's tread can be elevated through poorly drained areas by using rock, gravel, or earthen fill to create a causeway or turnpike. This permanently hardens the tread and is a useful technique when soils are poorly drained but do not have standing water as found in a wetland. A typical causeway is built by first defining the width of the trail tread with parallel rows of rocks or logs. The defining rows also serve to retain the fill. When in place, the filling process should begin with medium-sized stones that will allow water to pass under the causeway. Small stones, gravel, soil, or a mixture of materials should be added on top of the medium-sized fill to ensure a smooth walking surface. This surface should be rounded *2"* above the elevation of the defining logs or rocks to provide better drainage and to allow for settling.

A ditch can be dug parallel to both sides of the causeway to improve drainage. This variation is often called a turnpike.

The material excavated from the ditches can be used to help fill the causeway. To allow passage of water under the structure in areas of periodic flooding, small culverts should be used.

## Coweeta Dips

Coweeta Dips, or grade dips, are created when a short section of the trail is built with a grade slightly opposite to the prevailing grade. These are one of the most effective drainage techniques in trail construction, blend aesthetically into the landscape, and are almost maintenance free. They are cost-effective in controlling erosion and reduce the monotony of long, sustained grades. Coweeta Dips are most effective when built as part of the original trail construction, but can be used when relocating short problem areas if the terrain allows. On ascending trail segments the trail should level every 50 to 100 feet followed by about 15 feet of **slightly** descending trail before continuing upward. This almost imperceptible descent creates a dip (low point) and forces water coming down the trail to gently drain off. The dip itself requires no construction other than careful building of the trail to establish the dip's alignment. Care should be taken to ensure that the exit point of the drainage from the trail does not result in erosion.

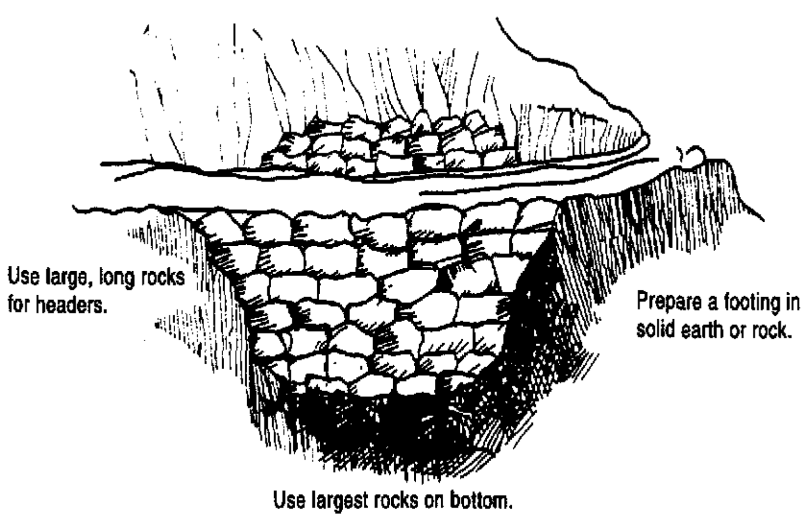



Since a place is needed to discharge the water, Coweeta Dips usually are best suited on sidehill trails. Coweeta Dips take advantage of the natural roll and drainage of the landscape. They should be positioned naturally into the terrain for maximum function without being obvious. Spacing should be varied to make the trail more interesting.

## Retaining Walls

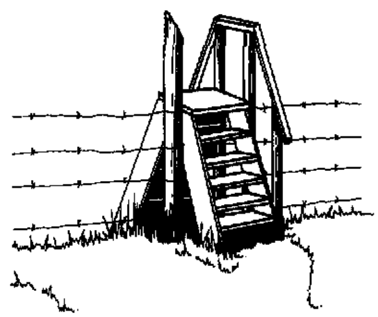
Retaining walls are structures of stone or wood designed to stabilize the trail base on steeper side slopes. They are time-consuming to construct but may be necessary to prevent soil slide or slump when sidehill trails are crossing the face of a slope that exceeds 40% to 50%. Retaining walls are a long-lasting investment; many constructed by the CCC in the 1930s are still functional today.

Sound, durable rocks with good, angular (rather than rounded) bearing surfaces are the preferred material because of their locking



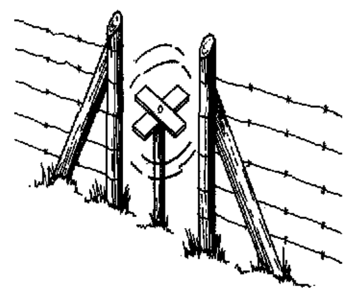
ability. Native decay-resistant or treated logs can also be used if rock is not available. The foundation must rest on solid earth or rock to obtain a rigid, safe retaining wall. The thickness of a rock retaining wall at the base should be at least one half the height of the wall or a minimum of 2′ if the vertical height is less than 5′. The outer face of the wall should have an inward slope of at least 2″ to 3″ for every foot of height. Drainage is required around, beneath, or through the wall so that water will not accumulate behind it and build up pressure, which could destroy the wall.

## Stiles



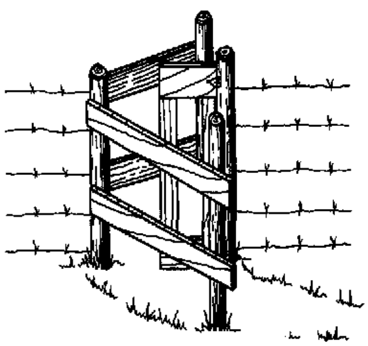
Step Stile

Stiles are typically used to pass over or through fences that surround pastures and other agricultural fields that most often occur on private land. These fences separate fields of different uses, as well as keep animals confined to a specific location. In these situations, it is important to work with the landowner to minimize the number of stiles required, and to ensure the type of stile(s) and location(s) is compatible with their needs. If stiles are used, turnstiles and dodgeways are the least problematic because they are partially accessible. Step stiles create a difficult barrier for many trail users and maintenance equipment such as mowers. They should be placed only when there is no other alternative. In areas where user conflicts exist, a stile can effectively serve as a barrier to unauthorized use by horses, bicycles, and ORVs.



Turnstile

Gates could serve the same purpose as a stile but they are more expensive to construct and maintain. There is also the possibility that a gate will be left open, allowing livestock to escape.



Dodgeway

## Water Bars

Water bars are structures that slow the flow of water and divert it off the trail. They work by reducing the speed, volume, and distance water travels down the trail. Traditionally, water bars have been built with rocks and logs, but other non-traditional materials, such as rubber belting, have also been used in recent years. These innovations offer greater accessibility to some, but may take away from the natural character of the trail.

During new trail construction, the use of water bars should be minimized through careful siting of the trail or by using Coweeta dips. However, where water flowing down the trail is anticipated, it is better to install water bars immediately than to wait for erosion to occur.

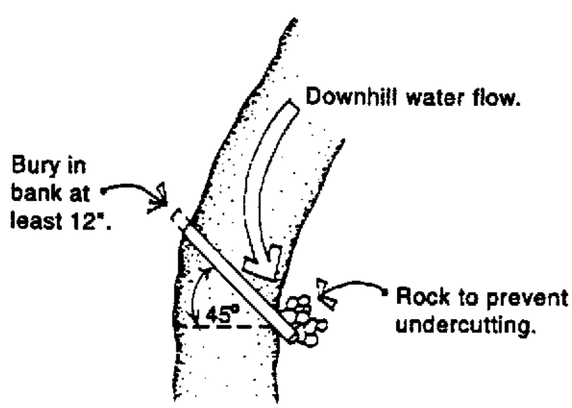
**Spacing -** Deciding on the actual number and spacing of water bars depends on the amount of water entering the trail, the steepness of slope, the construction of the treadway, and the availability of places to divert the water. Final placement of water bars is dictated by terrain. They must be placed where diverted water does not return to the trail. If this is not possible, a water bar should not be installed (e.g., where the trail lies in a high banked swale that requires extensive excavation in order for the water bar to function properly).

**Frequency of Water bars -** The greater the slope and the more water channeled by the trail, the greater the need for water bars. They should be placed below all points where a significant amount of water enters the trail. On uniform sustained grades, water bars should be placed near the top of the hill to divert water before it does damage, with others constructed periodically down the grade to keep water flow to a minimum.

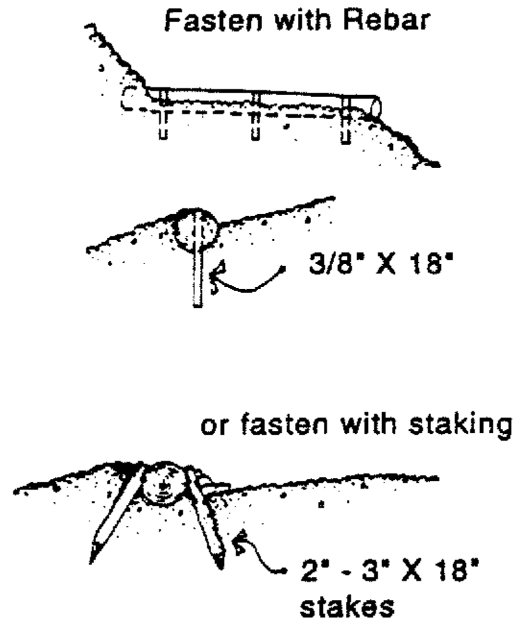
| *Material Type:* | *2% grade* | *4% grade* | *6% grade* | *8% grade* | *10% grade* | *12% grade* |
|---|---|---|---|---|---|---|
| **Loam** | 350' | 150' | 100' | 75'-50' | ** | ** |
| **Clay-Sand** | 500' | 350' | 200' | 150' | 100'-50' | ** |
| **Clay or Clay-Gravel** | -- | 500' | 300' | 200'-150' | 100' | 75' |

*Key: ** These grades are not recommended in this type of soil. -- No diversion required for soil stability.*

**Construction -** After water bar spacing and location is determined, a trench should be dug across the trail at about a 45-degree angle. Water bars may slow water too much, causing it to clog with silt and debris if placed at less than a 30-degree angle. Those placed at 45-degrees or more will tend to be self-cleaning. The trench should be deep enough to contain about 1/2 of the diameter of a log water bar or 2/3 of the height of the rocks used for a rock water bar. The water bar should be a minimum of *4"* above the level of the ground on the uphill side and should extend *12"* into the side of the hill and *6"* beyond the side of the trail on the downhill side. The water bar should be securely fastened in place using one of the techniques illustrated (right), or with stakes obtained on site.




Re-bars are often used to fasten log water bars in place. When used, holes are drilled through the log at a slight angle and the re-bars driven so that no portion protrudes above the log. If using native material for stakes, a tree *2"* to *3"* in diameter should be cut into *18"* pieces. The stakes should be driven on each side of the log water bar, with the tops of the stakes slanting over the bar, pinning the log to the ground. The stakes should be flush with the top of the water bar, excess should be trimmed to avoid creating a tripping obstacle or loosening that would result from being kicked.

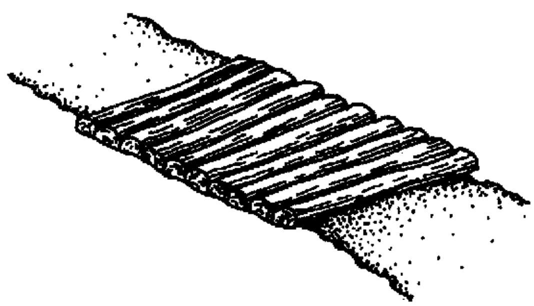



On the uphill side of the water bar the tread should be graded down into the trench. The trench should be deep enough to accommodate the amount of rain it will receive in a typical storm, yet not too high to interfere with the ease of the hiker. All excavated soil and rock should be placed on the downhill side of the bar and packed so the tread is flush with the top of the water bar. The best water bars are subtle, low structures, which are barely noticeable. Water bars require regular maintenance so that they continue to function properly. Accumulated soil and debris must be cleaned out at least annually.

## TEMPORARY MEASURES

### Corduroy

Corduroy construction is basically a primitive type of puncheon. It consists of laying native logs perpendicular to the trail to harden it through areas of unstable or saturated soil. If corduroy is left exposed, it provides uneven, slippery footing that is uncomfortable for the hiker, and does not convey the impression of a well-designed trail.



The installation of corduroy may also have environmental ramifications. Used in a bog or wetland situation, corduroy can change the natural flow of water, the water level, the species composition, or kill the upstream vegetation. Covered corduroy involves considerable modification to the site and is not recommended in the types of soils/sites where corduroy is typically employed. Wetland permits are usually required. Other alternatives such as puncheon or boardwalks are less intrusive on the site. Consequently, on the Ice Age NST, corduroy is not acceptable, except as a temporary measure until a more permanent solution can be installed, and then only in areas that are not defined as wetlands.

## STRUCTURES AND SITUATIONS TO AVOID

### Fords

Due to safety concerns, legal implications, and the "dry boot" philosophy, fords should not be used. Not only can it be unsafe to ford a stream, but descending steep, often slippery stream or ravine embankments can also be dangerous because of the possibility of falling or injuring oneself. Trails entering streams can also cause erosion and severely degrade stream quality.

Fording on new sections of trail should not be accepted and any fords on existing trail segments should be bridged as soon as funding is available.

## Steps and Perrons

Steps and perrons (elongated steps—more like a series of connected platforms) should be avoided. In most cases, proper trail layout can alleviate the need for steps. These structures are difficult and time consuming to properly construct and often create an unnecessary impediment. They make a difficult but otherwise accessible section of trail inaccessible. Even persons who are generally considered to be ambulatory, but who may have knee or hip problems, find steps more difficult to negotiate than gradual inclines.

In some cases there may be unavoidable topographical barriers, such as where an escarpment separates two moderately sloped grades, or land ownership patterns that restrict where the trail can be built, forcing the trail to traverse a hill at a much steeper-than-desirable grade. In these types of circumstances, steps may be the only alternative.

Step construction details are not provided (other than Appendix 1) since use of steps is limited. Local experts and a copy of the Appalachian Trail Conference's *Trail Design, Construction, and Maintenance* by Birchard and Proudman are good references.

## Stepping Stones

Stepping stones should not be used to cross streams. On navigable streams, or streams with fish populations, stepping stones are opposed by state agencies because they can create an artificial barrier to water flow or modify the fish habitat. Stepping stones also pose a barrier to accessibility and can become slick with moss and water—a falling hazard for everybody. Instead of stepping stones to cross streams, a bridge should be installed.

***Figure 2: Ice Age National Scenic Trail Design Standards for Trail Structures***

| **Standards (desired)** | **ROS CLASS** | | |
|---|---|---|---|
| | **Urban** | **Rural & Roaded Natural** | **Semiprimitive** |
| **Bridges (width)**<br>Hiking Segment<br>Accessible Segment | 60"<br>72" | 36"<br>48" | 36"<br>36" |
| Bridge Railings<br>Hiking Segment<br>Accessible Segment | Y<br>Y | (1)<br>(1) | (1)<br>(1) |
| Bridge Rail Height | 42" | 42" | 42" |
| Bridge Kickplate Required (2)<br>Hiking Segments<br>Accessible Segments | Y<br>Y | N<br>Y | N<br>Y |
| Puncheon (3)<br>Hiking Segments<br>Accessible Segments | N/A<br>N/A | 16-18" width<br>N/A | 16-18" width<br>N/A |
| Boardwalk (4)<br>Hiking Segments<br>Accessible Segments | 60"<br>72" | 36"<br>48" | 36"<br>36" |
| Culverts (5) | OK | OK | OK |

(1) Whether a railing is required is subject to policies of managing authorities, site characteristics, and common sense. Railings are almost always needed except, if the bridge is very wide, the crevasse shallow, or the length of the bridge very short.
(2) Kickplates are often included for safety when handrails are not required.
(3) Puncheon rests on sills and is generally less than 1' high.
(4) Boardwalk is generally less than 2' above water level and should have kickplates.
(5) Length must be calculated to provide for 2:1 fill slope beyond the normal trail clearing.
Size (engineering consultation) to accommodate peak flows. Water crossing permits often required.